[0015] FIG. **6** shows an exemplary embodiment of the invention having multiple transmitters and receivers.

[0016] FIG. **7** is a further example of a multi-transmitter configuration.

[0017] FIG. **8** is a schematic diagram of an ultrasonic power recovery chain. An effective load impedance, R_{in}, models the non-linear power recovery circuits, along with the implant power load, P_{load}.

[0018] FIG. **9** is an impedance plot of a 1.5 mm×1.1 mm×1.1 mm ultrasonic receiver made from PZT5H measured with an impedance analyzer (Agilent 4294A).

[0019] FIG. **10** is a schematic diagram of the one-dimensional series circuit model around fundamental resonance. The circuit elements are functions of material constants with length expander mode and dimensions as shown in the equations.

[0020] FIG. **11** is a diagram of an exemplary ultrasonic receiver package.

[0021] FIG. **12**A shows the measured R_{piezo} (solid line), the calculated R_{piezo} from the series circuit model (dashed line), and the measured power conversion efficiency, PCE (dotted line), of the receiver made from PZT4.

[0022] FIG. **12**B shows the measured R_{piezo} (solid line), the calculated R_{piezo} from the series circuit model (dashed line), and the measured power conversion efficiency, PCE (dotted line), of the receiver made from PZT5H.

[0023] FIG. **12**C shows the measured R_{piezo} (solid line), the calculated R_{piezo} from the series circuit model (dashed line), and the measured power conversion efficiency, PCE (dotted line), of the receiver made from $BaTiO_3$.

[0024] FIG. **13** is a conceptual diagram of a dynamic system with a programmable capacitive matching network and a closed-loop data link between IMDs and the external transmitter.

[0025] FIG. **14** is a schematic diagrams of the power recovery chain for off-resonance operation with series or L matching networks. The ultrasonic receiver is represented as a Thévenin's model. Z'_{in}, is the effective load impedance that the receiver sees before the matching network, and Z'_{piezo} is the input impedance seen from the non-linear power recovery circuit and loads.

[0026] FIG. **15**A shows simulated values of R_{piezo} (solid line), required R_{in} (dashed line) for optimal matching and capacitance, C_s (dotted line), as a function of P_{load} using the series matching network with the PZT4 receiver of section B4.

[0027] FIG. **15**B shows optimized PME with adaptive matching (solid line) and the PME without adaptive matching (dashed line) versus P_{load}.

[0028] FIG. **16** shows simulated total implant efficiency calculated from (1) with optimization of only PME (solid line) and co-optimization considering both PME and PCE (dashed line).

[0029] FIG. **17**A shows measured X_{piezo} and Q_{piezo} of the PZT4 receiver.

[0030] FIG. **17**B is a comparison of $\eta_{implant}$ from simulation of system using the L matching network (solid line), series matching network (dashed line), and non-adaptive system (dotted line). A boost in efficiency is observed throughout the relevant range of P_{load}. Measurements at six different P_{load} are represented by circles. ADS simulation and measurement are in good agreement.

DETAILED DESCRIPTION

A) General Principles

[0031] As indicated above, the main idea is a control system for ultrasonic power transmission to an implanted device having acoustic frequency as one of the variables under control. An exemplary embodiment of the invention is shown on FIG. **1**. This example is a system for providing power to an implanted receiver. It includes an acoustic transmitter **102** configured to provide acoustic radiation having an acoustic frequency f, a receiver unit **104** configured to be implanted into a biological subject, and a system controller **114**.

[0032] Receiver unit **104** is configured to receive the acoustic radiation and to be powered by the acoustic radiation. Receiver unit **104** includes an acoustic transducer **106** configured to receive the acoustic radiation and to provide an input electrical AC signal, an adaptively reconfigurable electrical impedance matching network **108** configured to receive the input electrical AC signal and to provide an output electrical AC signal, a power recovery circuit **110** and an electrical load **112**. The electrical impedance matching network **108** is capacitive without including any inductors. The power recovery circuit **110** is configured to receive the output electrical AC signal and to provide DC power to the electrical load **112**.

[0033] System controller **114** is configured to a) alter one or more controlled system parameters including the acoustic frequency f, and b) alter a configuration of the adaptively reconfigurable electrical impedance matching network; responsive to changes in one or more system variables to control power delivery from the acoustic transmitter to the electrical load. Practice of the invention does not depend on where the components of the system controller are located. System controller components can be on a separate unit (e.g., **114** on FIG. **1**), and/or can be included on transmitter **102** and/or can be included in receiver unit **104** in any combination. The initial operating point of the system could have been designed with specific properties and then the system could have calibrated itself using sensing and system reconfiguration at startup and during operation.

[0034] As indicated above, it is preferred for the system to be operating at or near a frequency range where the transducer reactance is positive. Here a "positive reactance band" of an acoustic transducer is any frequency band in which the acoustic transducer provides a positive reactance (i.e., has a positive imaginary part of its electrical impedance). The "inductive band" of an acoustic transducer is any positive reactance band of the acoustic transducer+/−20% in frequency. More specifically, if the positive reactance band is $f_1 \le f \le f_2$, the corresponding inductive band is $0.8\, f_1 \le f \le 1.2\, f_2$. Preferably the system operates in the inductive band as defined above.

[0035] In preferred embodiments, the acoustic frequency is controlled by the system controller such that the impedance of the acoustic transducer (e.g., Z**1** on FIG. **2**) is tuned to impedance match the impedance as seen at the input of the adaptively reconfigurable electrical impedance matching network for an electrical load (e.g., Z**2** on FIG. **2**). "Impedance match" as referred to herein denotes an exact impedance match or an approximate impedance match to within 50% (i.e. considering the reflected power to be within 50% of available power). More specifically, two complex impedances Z**1** and Z**2** are matched if Z**1**=Z**2*** (where * denotes